THE UNIVERSITY OF TEXAS AT AUSTIN

REPORT ON THE

LUNAR RANGING

at

McDONALD OBSERVATORY

FOR THE PERIOD

OCTOBER 16, 1974 TO FEBRUARY 11, 1975*

by

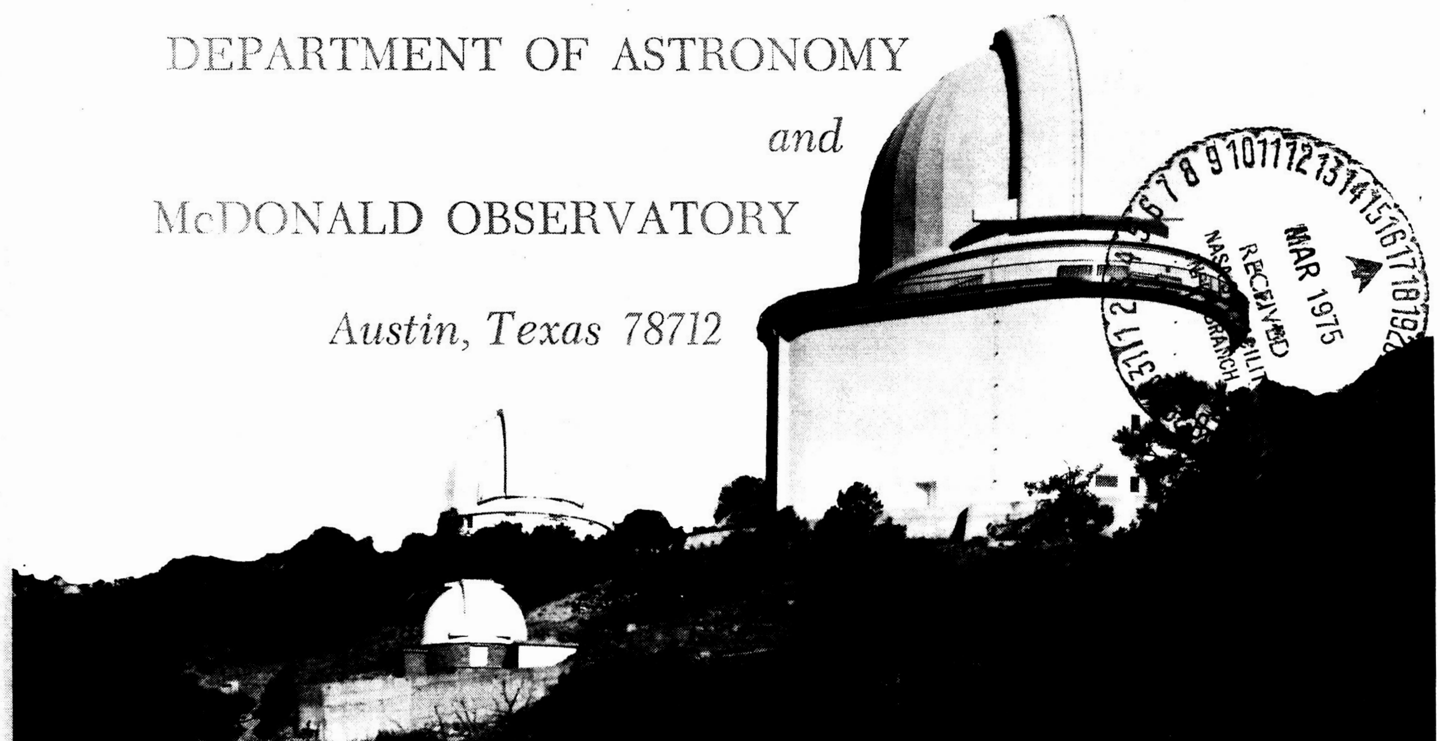
E. C. SILVERBERG

DEPARTMENT OF ASTRONOMY

and

McDONALD OBSERVATORY

Austin, Texas 78712



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ABSTRACT

The four lunations between 16 October, 1974 and 11 February, 1975 were active in our continuing program to upgrade the capabilities of the McDonald Lunar Laser Ranging Station. Numerous changes were installed during this period designed to increase the overall reliability and performance of the laser equipment. The ranging operations proceeded routinely but at a somewhat slower acquisition rate due to relatively poor weather and the intermingled R & D efforts.

TABLE OF CONTENTS

I. SYSTEM RANGING OPERATIONS

The laser operations crew attempted 105 range acquisitions during the four lunations covered by this report and were successful 66 times for a 63% success rate. The character of the operations for the period can be followed with the aid of the daily log sheets which are included, as usual, in Appendix A. The first lunations were relatively routine, with 49 range observations divided between them. Following the second lunation we stopped operations for a full two weeks to install the new detector package and the hardware and software associated with the T. V. Guide system (Section III-B). The two lunations following were some of the poorest we've had in five years at McDonald. Long stretches of cloudy weather coupled with the appearance of the high altitude jet stream permitted only 33 attempts and seventeen successful ranges during the last two months. The pressure on the ranging crew simply to supply a reasonable number of acquisitions during this period greatly slowed our work with the automatic guiding system. Table I summarizes some of the essential factors relevant to the ranging effort. The relatively modest totals do not indicate any equipment or operations problems at the site, and, for the most part, were caused by factors beyond our control.

We bring the reader's attention to a number of corrections which we must make to our last McDonald Report. Following the November lunation a calibration error was discovered which affected all of the data since August of 1974 (Section II-A). These calibrations errors also required that we reassess the data uncertainty estimates reported earlier (Section II-B), as well as the performance of the laser (Section III-B). In short, we regret to report that most of the 6 centimeter ranges, believed to have been measured in the summer, were an artifact of our calibration error and must now be down-graded in accuracy by 20 to 40 percent.

A low point of the last four lunations came on January 30th when we attempted an all night laser run. In spite of apparently good conditions we were unable to acquire enough signal on the Apollo 15 corner reflector to get the desired 8 centimeter range accuracy. The cause is still unknown. Peculiarities such as this have caused us to look deeper into our own data as well as the current literature concerning possible modes of degradation for the corner reflectors. As yet, we find no evidence for any degradation in our data, but we continue to pursue the topic for possible clues regarding long term effects (Section III-E).

No personnel changes occurred during the last quarter and no travel other than trips to the University in Austin.

TABLE I

LRRR	# Attempts	# Shots	# Returns	# Ranges	Aver. PE/shot Sig.
11	17	3137	52	6	.017
14	19	3601	56	10	.016
15	65	13172	463	49	.035
21	4	762	6	1	.008
All LRRR	105	20672	577	66	.0279

II. DATA REDUCTION NOTES

A) Calibration Changes

Problem: Detailed reduction of the lunar ranging data for the August-September and the September-October lunations indicated that the tight laser feedback pulse reported in the previous quarterly report was not mimicked by the lunar returns. Not only was the return distribution much wider than the feedback data; but, in some cases, double pulse structure was also seen. At the request of Pete Shelus the calibration data was redone in an attempt to find the cause of this discrepancy.

Cause: The laser feedback data, which has been our basic calibration method since 1971, involves measuring approximately a 3-foot range with the receiver photomultiplier system. In order to prevent noise contamination of the feedback data, it is necessary to gate the electronic system only tens of nanoseconds ahead of the expected feedback pulse. Contrary to expectations, it has been found that the gate pulse has a considerable effect on the measured time delay if it occurs within 15 nanoseconds of the arrival of the feedback signal. Prior to August 28, 1974 the gate signal was generated with a separate photodiode. With the possible exception of the interval between 1 December, 1971 and 5 December, 1972 the gate signal preceded the arrival of the feedback return by the necessary amount. On 28 August, 1974, we stopped using a separate diode to generate the gate signal. Being unaware of the potential problems we put the new gate signal too close to the arrival of the photomultiplier pulse, greatly compressing the time scale for the feedback events as well as adding a systematic offset.

Recovery: Since we had not modified the electronic timing system before the error was discovered, it was possible to calibrate the effects of the close gate pulse on the 1974 data. Additional data reduction cards were immediately sent to the analysis group in Austin, and the results of this recovery were included in the original data distribution. Since the recovery involved a well-understood correction to otherwise reasonably accurate feedback data, it could be accomplished with little loss of accuracy. The corrections to previously published calibration constants are given in Appendix II.

At this late date it is not possible to assess the effects of the close gate pulse on the 1971 and 1972 data. We have been able to establish, however, that the ranges taken between 1 December, 1971 and 5 December, 1972 will be between zero and 1.2 nanoseconds too short. All of the data in this period will be affected by a constant, systematic offset. We suggest that an additional term be added to the analysis solutions to deduce the possible effects of this problem.

Cure: The present system configuration dictates that we use the same start diode to both initiate the 2½ second range determination as well as gate the feedback return. A delay cable and an additional discriminator have been added to the path of the start pulse in order to insure that the proper sequence and time delays will be maintained in the future.

B) Laser Pulse Length

The close gate pulse mentioned earlier caused compression of the time domain of the feedback timing. The result was a mistaken impression that we had a very short laser pulse such as was mentioned in the October quarterly report. We regret to say that the laser pulse length and hence, the single shot uncertainty, has not appreciably changed over the last six months. Corrected estimates of the single shot uncertainty for days 240-284, 1974 are given in Appendix II. The best of these calibration measurements, when coupled with good lunar signals, translate into range uncertainties of about 7-8 cm.

C) Pressure Data

At the suggestion of J. D. Mulholland, the manually tabulated pressure data taken by the laser crew was compared with Observatory chart recordings on a number of selected months spaced over the last four years. With the exception of one or two errors, which appear to be keypunch mistakes, it appears that the pressure data is quite accurate. The long periods of nearly constant pressure, which flagged the possible error, were confirmed by the chart recordings and merely indicate that we do not operate the laser experiment during adverse weather conditions.

D) Range Effects due to Telescope Focus Selection

As pointed out by Mulholland and Shelus, the range analysis must include the effect of the two-way path from the intersection of the telescope axes through the 2.7 meter reflector. This path adds an additional 18 meters to the lunar range measurements in addition to the geometric correction given by the ranging crew. ("The telescope is not an infinitely small device located at the intersection of the equatorial and declination axes.") In this same light, the movement of the secondary mirror adds or subtracts four times that distance from the range measurements. Fortunately, the amount of motion which occurs in the 2.7 meter McDonald reflector will not be significant in the lunar ranging experiment. Various focal positions assumed by the ranging crew merely compensate for the thermal expansion and contraction of the main telescope barrel. Thus, for a fixed coude focus position, the path length remains constant. The only change in effective focal position over the last three years was associated with the installation of the television guiding system during December of 1974. At that time the secondary was moved to an average position of 2.2 mm farther from the intersection of the telescope axes. This repositioning systematically increased the lunar range by approximately 9 mm, a negligible value with our present range uncertainties.

III. RESEARCH AND DEVELOPMENT

A) Detector Package Changes

A new detector package was installed during the December new moon break to replace the well-worn unit supplied by the University of Maryland some five years ago. Pictures of the exterior and interior compartments of the detector package are shown in Figures I and II. The need for a spacial adjustment on the photomultiplier position has been apparent for some time, particularly when using the galium-arsenide photomultipliers which have a relatively small cathode. Since it is impossible to transmit an appreciable amount of light through the 1.2 angstrom interference filter, it is necessary to peak the photomultiplier signal on a standard source following the alignment of the rest of the detector package. The series of concentric rings, shown on the back of the detector package in Figure I, allows this motion without sacrificing the light integrity of the package.

The major reason for modifying the detector package was to replace the air-drive shutter with a torque motor device. Vibration from the air shutter could be felt in the coude frame even tens of feet from the package and was probably a major cause for the apparent lack of stability in the laser alignment. The new shutter arrangement consists of a 2 aperture wheel which is spun into position with a DC torque motor. The alternate positions are either clear or contain an N.D. 9 filter for attenuating the feedback path. The new shutter arrangement has considerably less vibration than the air-driven model.

A chamber was added to the so-called brass egg, which provides the shielding for the photomultiplier, during the December down time. It is hoped that the addition of a

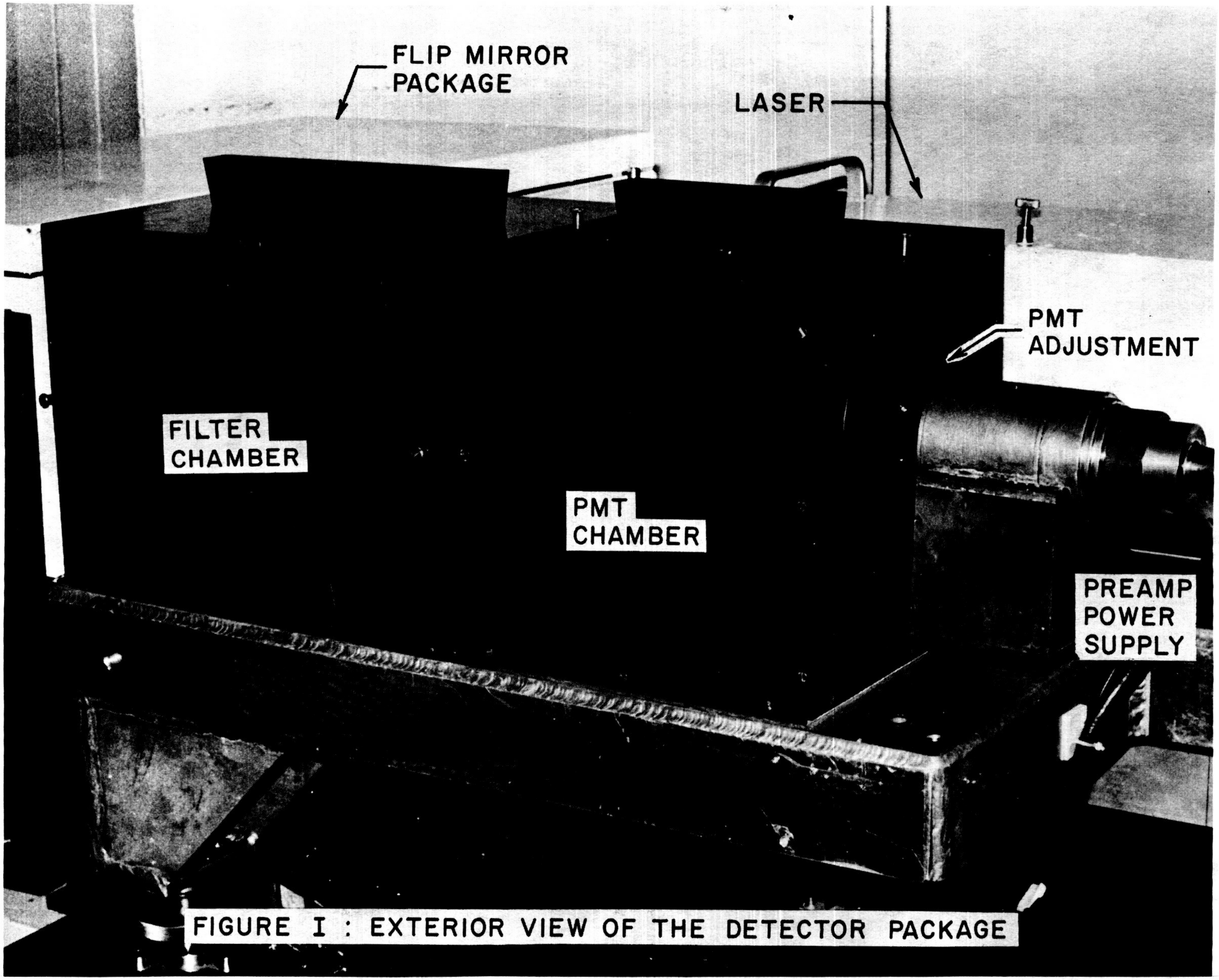

FIGURE I : EXTERIOR VIEW OF THE DETECTOR PACKAGE

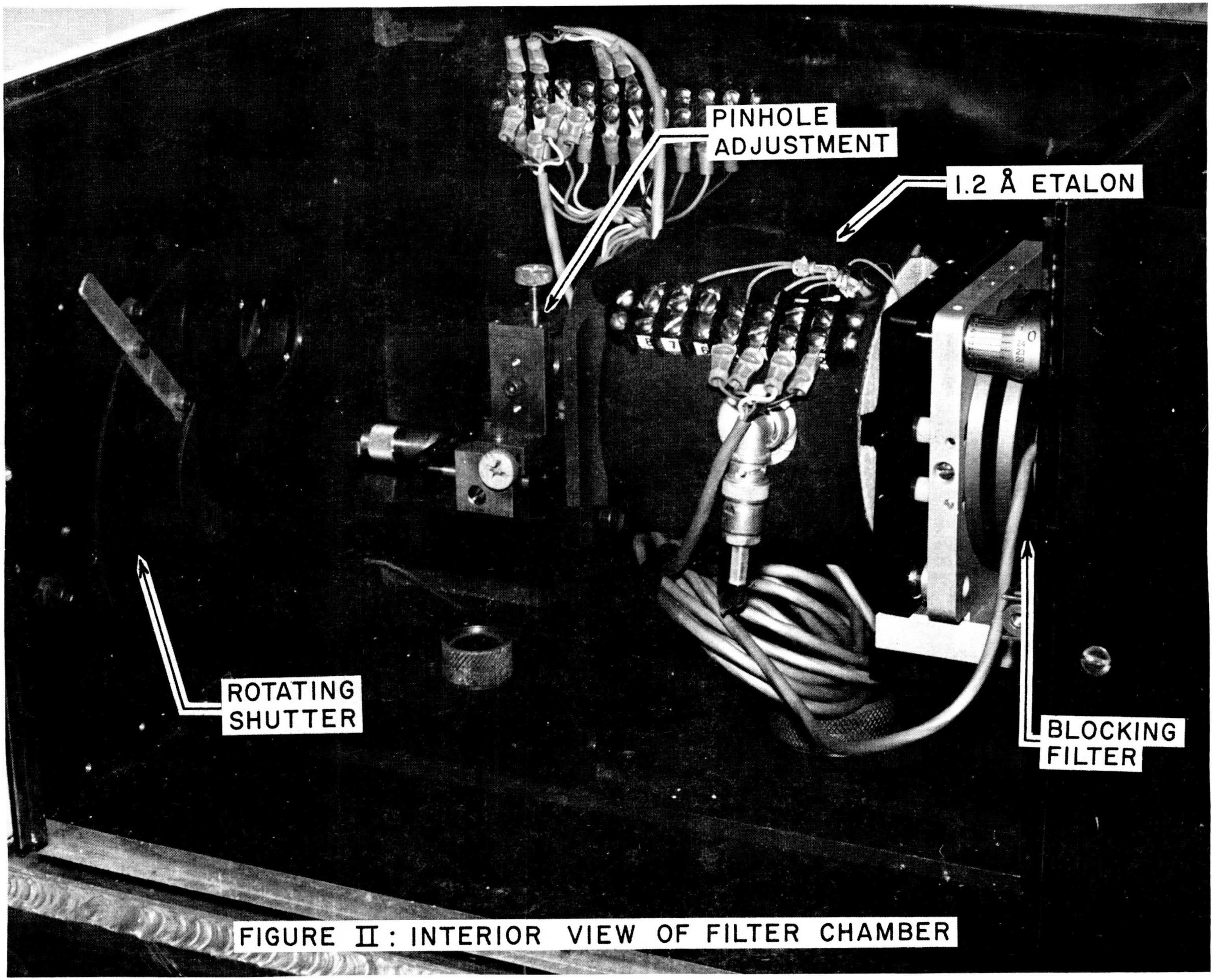

FIGURE II : INTERIOR VIEW OF FILTER CHAMBER pre-amplifier in the photomultiplier base will allow the routine operation of the galium-arsenide photomultipliers. It is now very difficult to operate with these high efficiency tubes due to a conflict between our system gain requirements and peak anode currents specified by the manufacturer. The installation of a high-speed op-amp pre-amplifier should greatly alleviate the problem.

B) The Installation of the TV Guider

The hardware for the TV Guiding system was also installed during the December new moon break. This required the installation of a pellicle splitter in the beam of our reducing objects. Twenty percent of the light was diverted towards the silicon diode camera. A long pass filter transmitting >7000 Å was used to eliminate the visible part of the spectrum and reduce chromatic effects. The auxiliary electronics for the camera guider were installed in a new console along with the track rate selection box and a monitor screen. A view of the current guide station is shown in Figure III.

The camera was first used during the December-January lunation. At that time it was found that the software which had been developed for the system was not sufficiently complex to handle the wide range of possible conditions. Upgraded software, permitting a much greater latitude of operating conditions, was installed during the January new moon break. The lack of much operating time during the January-February lunation has prevented the complete debugging of this new package. As of this date, the camera is useable on occasion, but is not yet what we would term operational. We will report the development of the device in the open literature at the appropriate time.

C) Air Watch Station

On a lighter note we draw attention to Figure IV showing a contribution to laser ranging by our Physical

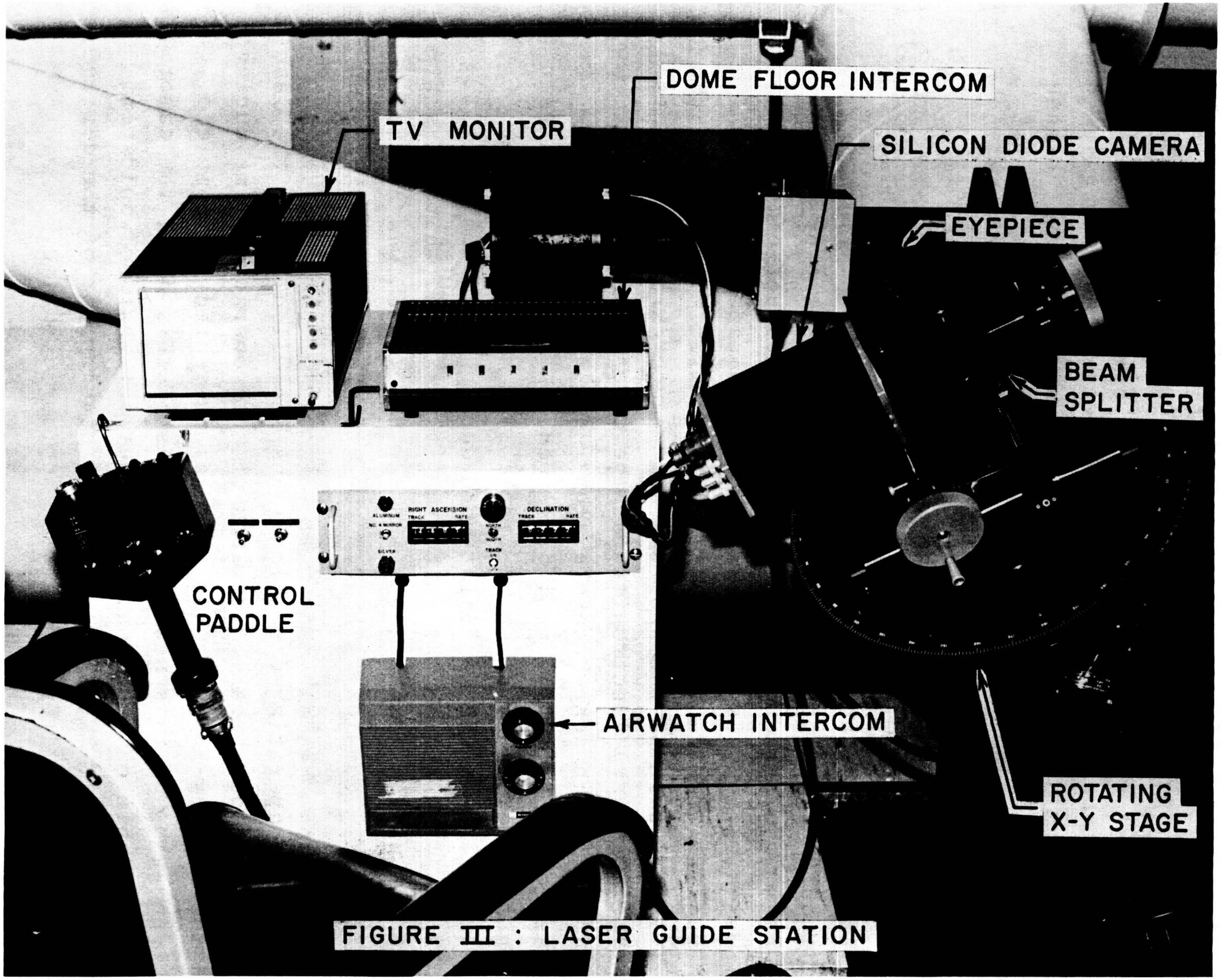

FIGURE III : LASER GUIDE STATION

Plant Division. This little hut, aptly nicknamed "The Igloo", is cantilevered from the southernmost extension of the 107" catwalk. Equipped with an intercom, laser shutdown switch, foot heater and radio, it should make airplane watch a little more bearable between the months of November and May.

D) Status of the Laser Upgrade

The calibration error reported in Section II-A successfully hid the double pulse structure in our laser for several months. Following the electronics correction it was necessary to renew our laser research. As we have mentioned earlier, the laser has now been modified to use dielectric, thin-film polarizers, rather than the calcite prisms, to create the short pulse. Manufacturing difficulties have greatly limited the lifetimes of these thin-film devices. This is still a problem; but, through careful control of our laser energy, we have now been able to use a thin-film polarizer for over a month of continuous operation.

The new laser oscillator cavity is very sensitive to gain variation. Good single-pulse operation requires that you keep the gain in the oscillator cavity as near constant as possible. Knowing this, we have been able to maintain good operation by varying the pumping level of the oscillator flash lamps. The laser operator does this on a run-by-run basis, monitoring the output of the system on a high-speed oscilloscope. Aside from this unforeseen nuisance the new laser system appears to be operating well. We now have the option of transmitting a laser pulse somewhat shorter than 2 nanoseconds which should be compatible with obtaining 3 to 4 centimeter range measurements on the

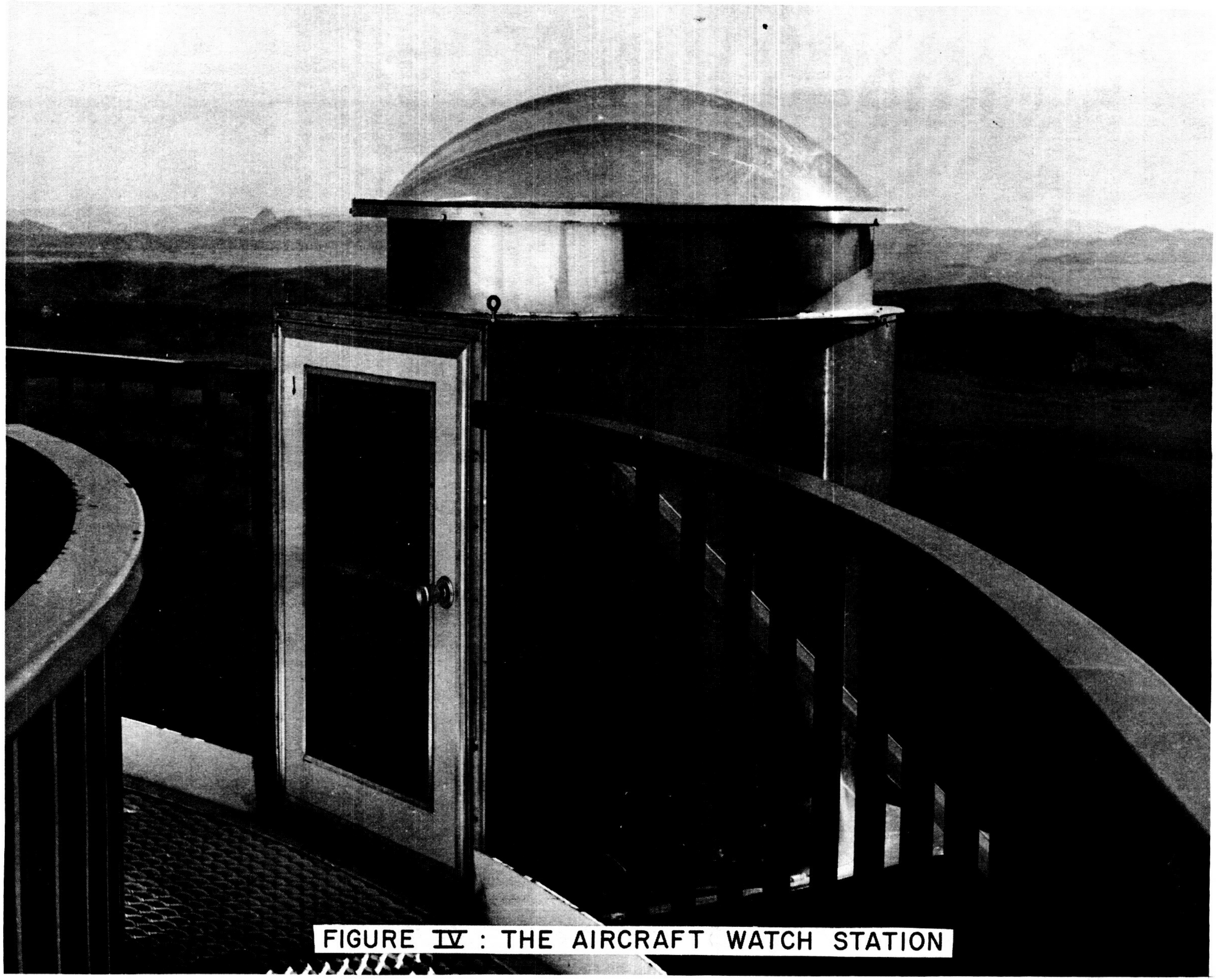

FIGURE IV : THE AIRCRAFT WATCH STATION

Apollo 15 corner reflector. Figure V shows our current laser pulse width as measured by the feedback electronics. The laser pulse width is approximately 2.1 nanoseconds, FWHM as measured by the auxiliary time-to-pulse-height unit. Additional width is added by jitter in our timing electronics, resulting in a single shot uncertainty, at least for this day, of $\pm$ 1.8 nanoseconds.

E) Lunar Dust Research

Much data has accumulated to indicate that the dust flux near the lunar surface is many orders of magnitude higher than that expected from an interplanetary micrometeorite source. This additional dust flux is undoubtedly caused by electrostatic effects during terminator passages on the moon. Because of the obvious possibility of the dust flux affecting the optical performance of the lunar corner reflectors, the project scientist has spent several weeks during this reporting period assessing the effects of such a mechanism. Although the study is far from complete, it appears that the dust flux, depending on the geometry of the nearby terrain, could vary by as much as several orders of magnitude from site to site or even from month to month. Thus, it is impossible to come up with accurate lifetime measurements based on data now available in the open literature.

Failing in the theoretical approach we consider our lunar ranging data as empirical evidence for the upper limit to the dust coverage on the three corner reflectors. At the present time, we find <u>no evidence</u> for any appreciable change in overall signal from any of the three Apollo corner reflectors. Thus, we place an upper limit to the possible dust coverage as that which would shield a few percent of the surface. While we may not be able to

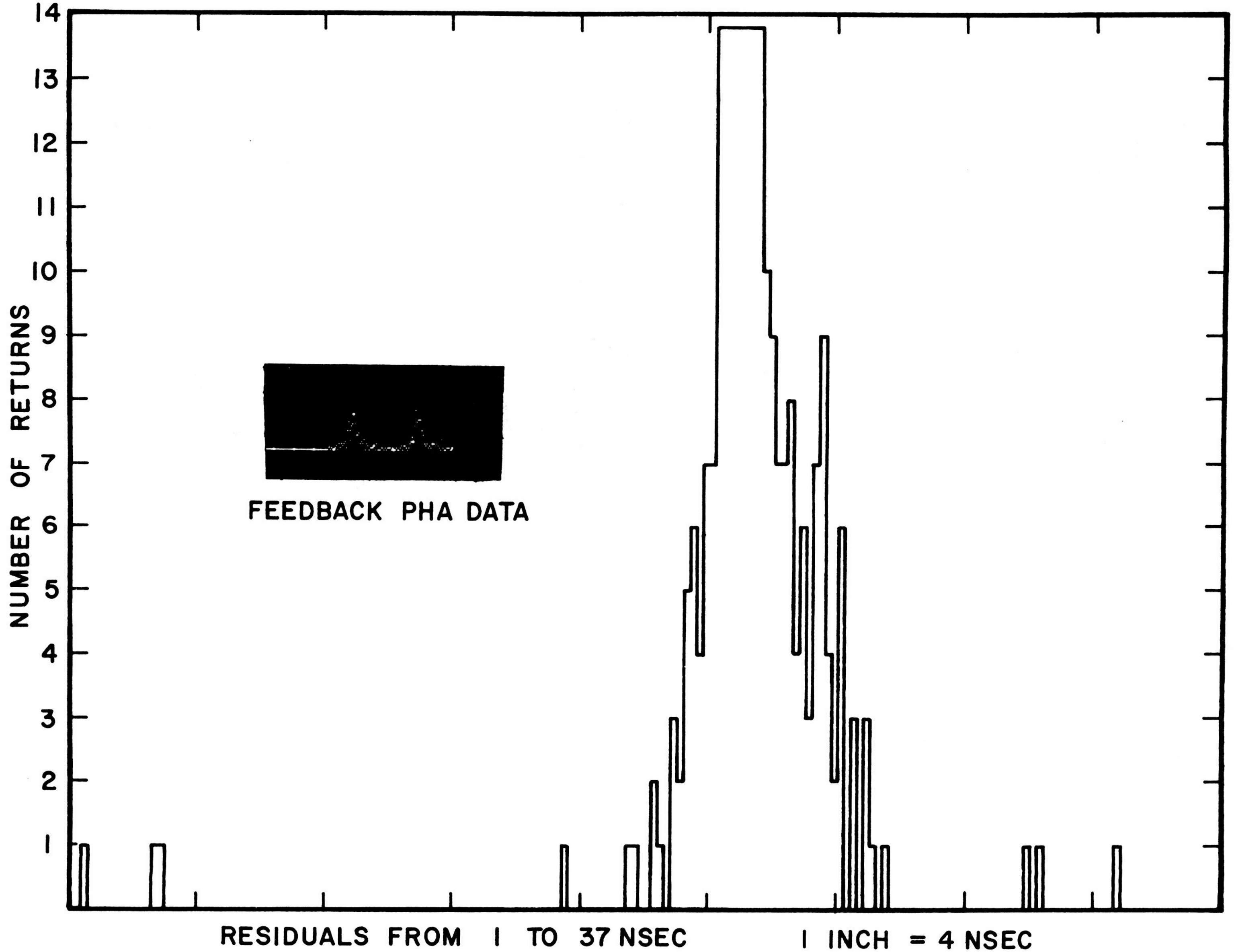

FIGURE V : LASER FEEDBACK DATA ON 7 FEB. 1975 make any conclusions as to the long range performance of these devices, we at least know that they will be available throughout the next decade. A more complete report will be published when this study is concluded.

APPENDIX A

The McDonald Lunar Laser Operations Log

from

16 October, 1974 to 11 February, 1975

STATION LOG NOVEMBER 1974

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Oct. 19	292	2200-0200				ptly cldy	8	cancelled-bad seeing
Oct. 20	293	2150	403	219/4	0/4	ptly cloudy	2-3	changed delay cable after 150 on #4
			404	224/0	0/0	"	"	
		0200				ptly cldy		cancelled-clouds
Oct. 21	294	2100-0200				cldy		cancelled-clouds
Oct. 22	295	2200-0200				cldy		cancelled-clouds
Oct. 23	296	2300-0500				cldy		cancelled-clouds
Oct. 24	298	0000				cldy		cancelled-clouds
		0400	405	190/3	12/3	ptly cldy	4	
			406	228/0	0/0	"	"	
Oct. 25	299	0130	407	94/3	11/3	clear	3-4	
		0530	408	131/3	10/3	clear	"	
			409	241/2	0/2	"	"	
Oct. 26	300	0100	410	92/3	10/3	clear	3	
			411	246/2	10/2	"	"	
			412	188/0	10/0	"	"	

STATION LOG NOV. 1974 CONT.

DATE	DAY(GMT)	TIME	RUN NO	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Oct. 26	300	0340	413	150/3	10/3	hazy	3-4	
Oct. 27	301	0100	414	162/3	0/3	ptly cldy	3	stopped by clouds
		0500	415	122/3	13/3	clear	3	
			416	297/2	9/2	"	"	
			417	223/0	0/0	"	"	
Oct. 28	302	0130	418	253/3	10/3	clear	4-6	image motion
		0600	419	167/3	10/3	"	3	
			420	271/2	10/2	"	"	
			421	142/0	0/0	"	"	
Oct. 30	303	0230	422	222/3	11/3	clear	4	
			423	277/2	6/2	"	"	
		0730				cloudy		cancelled
Oct. 30	304	0415	424	232/3	0/3	ptly cldy	4	
		0830				clear	4-7	cancelled-bad seeing
Oct. 31	305	0430	425	298/3	13/3	clear	3	adjusted detector
			426	232/2	6/2	"	"	

STATION LOG NOV. 1974 CONT.

DATE	DAT(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Oct. 31	305	0930	427	94/3	11/3	clear	2	
			428	141/0	10/0	"	"	
Nov. 1	306	0430				cloudy		cancelled
		0730				cloudy		cancelled
		1130	429	214/3	10/3	clear	4	
			430	95/0	0/0	"	4-7	stopped by bad seeing
Nov. 3	307	0630	431	194/3	13/3	clear	4	image motion
		0930	432	92/3	9/3	"	"	" "
			433	35/0	0/0	"	"	blew osc. flashlamp-probably 2 returns
		1230	434	189/3	9/3	ptly cldy	3	light to heavy cirrus-image motion
			435	287/0	4/0	" "	"	" " "
Nov. 4	308	0730				cirrus	6-9	cancelled-bad seeing & cirrus
		1030				cirrus	5-6	" " "
		1330				cirrus	3-4	cancelled-cirrus (ground fog)
Nov.5	309	0830				clouds		cancelled

STATION LOG NOV.1974 CONT.

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Nov. 5	309	1230				clouds	3-4	cancelled
		1330	436	78/3	10/3	cirrus	3	
			437	384/2	4/2	"	"	
			438	177/4	6/4	"	"	
			439	99/3	8/3	"	"	
Nov. 6	310	0930	440	135/3	12/3	clear	2	
			441	118/2	11/2	"	"	
		1230-1530				cloudy		cancelled
Nov. 7	311	1030-1630				cloudy		cancelled
Nov. 8	312	1100-1700				cloudy		cancelled
Nov. 9	313	1145-1745				cloudy		cancelled
Nov. 10	314	1245-1845				cloudy		cancelled

Attempts	Successful measurements
9/0	3/0
8/2	7/2
20/3	18/3
2/4	1/4

STATION LOG NOV.-DEC. 1974

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Nov.18	322	1930				cloudy		cancelled
		2230				"		"
	323	0130				cirrus		cancelled-cirrus, laser problems
Nov. 19		2030				cirrus		" " "
		2350	442	120/0	0/0	clear	2-5	stopped by deter-iorating seeing
	324	0200	443	281/3	3/3	clear	4-7	bad seeing
Nov. 20		2115				cirrus	4-6	cancelled-seeing, contrast
	325	0000				cloudy		cancelled
		0300	444	284/3	0/3	cirrus	4-5	bad seeing
Nov.21		2200	445	221/3	0/3	clear	4-5	bad seeing & contrast
	326	0100	446	181/3	7/3	clear	3	
			447	141/0	11/0	"	"	
			448	82/4	0/4	"	"	
		0330	449	171/3	11/3	clear	3-5	
			450	268/0	0/0	"	"	
Nov. 22		2245				cloudy		cancelled
	327	0145				"		"

STATION LOG NOV.-DEC. 1974 CONT.

DATE	DAY (GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Nov. 22	327	0500	451	304/3	0/3	ptly cldy	4-6	bad seeing
Nov. 23		2330				cloudy		cancelled
	328	0230				ptly cldy	8-10	cancelled-poor seeing
		0530				" "	"	" " " & clouds
Nov. 24	329	0000				clear	8	cancelled-bad seeing
		0315	452	279/3	8/3	clear	4-6	not very good seeing
			453	186/0	0/0	"	"	" " "
Nov. 25		0600	454	240/3	11/3	clear	4	
			455	260/2	0/2	"	"	
Nov- 25	330	0100	456	210/3	8/3	clear	3-5	
		0345	457	132/3	10/3	clear	3-5	
			458	325/2	5/2	"	"	
Nov.26		0645	459	191/3	0/3	clear	4-6	stopped by bad seeing
	331	0200	460	315/3	7/3	clear	3	
		0500	461	158/3	25/3	"	2	
			462	317/0	8/0	"	"	
Nov. 27		0800	463	113/3	10/3	cirrus	3	
	332	0230	464	284/3	11/3	clear	3	

STATION LOG NOV.-DEC. 1974 CONT.

DATE	DAY (GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Nov. 27	332	0515				cloudy		cancelled
Nov.28		0815	465	378/3	9/3	clear	3	
	333	0300				cirrus	7-9	cancelled-seeing, cirrus
Nov. 29		0600				cloudy		cancelled-fog, clouds
		0900				"		" " "
	334	0400				clear	7-9	cancelled-seeing
Nov. 30		0700	466	319/3	9/3	clear	4	
		1000	467	354/3	11/3	clear	4	
	335	0500				cloudy		cancelled
Dec. 1		0800				"		" "
		1100				"		" "
Dec. 2	336	0600				"		" "
		0900				"		" "
		1200				"		" "
Dec. 3	337	0700				"		" "
		1000				"		" "
		1000				"		" "
Dec. 4	338	0800	468	136/3	5/3	clear	2	

STATION LOG NOV.-DEC. 1974 CONT.

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Dec. 4	338	1100				cloudy		cancelled
		1300	469	61/3	5/3	ptly cldy	2	stopped by damaged polarizer
Dec. 5	339	0900				ptly cldy		cancelled, damaged polarizer & alignment problems
		1200	470	7/3	0/3	ptly cldy		" " "
		1500				" "		" " "
Dec. 6	340	1000				clear		cancelled, high wind
		1300				"		" " "
		1600				"		" image motior
Dec. 7	341	1045	471	67/2	0/2	clear	4	
		1330	472	213/2	0/2	"	4-6	
		1635	473	37/2	0/2	"	"	blew flashlamp

ATTEMPTS	SUCCESSFUL MEASUREMENTS
5/0	2/0
6/2	2/2
21/3	16/3
1/4	0/4

STATION LOG DEC. 1974

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Dec. 15-20	349-354							runs cancelled updating equiptment
Dec. 21	355	22:00					2	cancelled tdg prob.
	356	01:00	474	224/3	5/3	clear	3	dis. at 3.50 pmt 2900v.auto guide in core no bio
		03:20	475	246/3	7/3	cirrus	3-4	
Dec. 22	356	22:45	476	117/3	0/3	clear	4	pmt 2950v. dis. 3.70
		00:00	477	295/3	11/3	"	2	
		03:00	478	171/3	0/3	"	3	
			479	84/2	0/2	"	3	pmt 2700v. g=4 int5 d=3.0
Dec. 23	357-358	23:30- 02:00				clear	5	cancelled seeing image motion
	358	05:30				clouds	4	canc. clouds
Dec. 24	359	00:30 06:30				"		cancelled
Dec. 26	360	01:00 07:00				"		"
Dec. 27	361	01:45 07:45				"		"
Dec. 28	362	02:30 08:30				"		"
Dec. 29	363	03:30 09:30				"		"
Dec. 30	364	04:30 10:30				"		"
Dec. 31	365	05:30				"		"
		08:30				clear	10	canc. seeing wind
		11:30				cirrus	8-12	" " "
Jan 1,75	1	06:30 12:30				clouds		cancelled

STATION LOG DEC. 1974 & 75

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Jan. 2	2	07:45 13:45				clouds		cancelled
Jan. 3	3	08:30				clear	4-5	canc. cheb problems
		11:30				clouds		cancelled
		14:00				ptly cld.	6-8	cancelled seeing
Jan. 4	4	09:30				clear	8-10	" "
		12:30	1	309/3	10/3	"	3-4	image motion
		15:00	2	140/3	0/3	"	5-6	bad image motion
Jan. 5	5	10:30				cirrus	8-12	g=2 2850v pmt disc=3.3
		13:30				"	"	wind 40 to 45mph
		15:30				clear	6-8	canc. seeing image mot.
Jan. 6	6	11:30	3	276/2	0/2	clear	4-6	bad image motion
			4	174/3	0/3	"	"	" " "
		14:30	5	134/2	0/2	"	"	" " "
		16:30				"	"	" seeing contrast
Jan. 7	7	12:00 16:00				clear	4-6	canc. seeing image mot.
Jan. 8	8	13:00 17:00				"	5-6	" " " "

ATTEMPTS	SUCCESSFUL MEASUREMENTS
0/0	0/0
3/2	0/2
7/3	4/3
0/4	0/4

STATION LOG JANUARY 1975

DATE	DAY(GMT)	TIME	RUN. NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Jan. 17	17	1900				clear	4	used for tests
		2200	6	284/4	2?/4	clear	4	luna 21 slightly
			7	191/3	4?/3	clear	4	illumnated
		2300						used for occultation
Jan. 18	18	2000				clear	7-9	cancelled
		2200				clear	7-9	cancelled
		2330				clear	7-9	cancelled
Jan. 19	19	1940				clear	8-10	cancelled
		2200				clear	8-10	cancelled
	20	0000				clear	8-10	cancelled
Jan. 20	20	2300	8	180/3	12/3	clear	3	trouble with cooler
	21	0130	9	92/3	7/3	clear	3	good laser pulse
			10	182/0	9/0			K's a little short
			11	106/2	0/2			
			12	72/3	7/3			
Jan. 21	21	2230	13	191/3	10/3	clear	3-4	longer delay cable
			14	268/3	10/3			
	22	0300				cloudy		cancelled
Jan. 22	22	2300				cloudy		cancelled
	23	0400				cloudy		cancelled
Jan. 23	23	2315				cloudy		cancelled
	24	0400				cloudy		cancelled
Jan. 25	25	0030				clear	6-8	wind 30 to 35 MPH
		0330	15	370/3	5?/3	clear	3-4	first 150 shots trouble with shutter
Jan.26	26	0100				clear	5-6	lots of noise blanking in first 150 shots
		0440	16	251/3	9/3	clear	3	
			17	184/0	0/0	clear	3	
Jan. 27	27	0210	18	342/3	4/3	clear	2	-4.5 to 3.7 H.A.
		0330	19	171/3	0/3			very poor signal
			20	176/0	0/0			cancelled after
			21	97/3	0/3			meridian crossing
		0600	22	200/3	0/3	clear		

STATION LOG JANUARY 1975

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Jan. 28	28	0430				cloudy		cancelled
		0830				cloudy		cancelled
Jan. 29	29	0530				cloudy		cancelled
		0930				cloudy		cancelled
Jan. 30	30	0630				cloudy		cancelled
		0930				cloudy		cancelled
		1230				cloudy		cancelled
Jan. 31	31	0730				cloudy		cancelled
		1030				cloudy		cancelled
		1330				cloudy		cancelled
Feb. 1	32	0830				cloudy		cancelled
		1130				cloudy		cancelled
		1430				cloudy		cancelled
Feb. 2	33	0930				cloudy		cancelled
		1230				cloudy		cancelled
		1530				cloudy		cancelled
Feb. 3	34	1015				cloudy		cancelled
		1315				cloudy		cancelled
		1615				cloudy		cancelled
Feb. 4	35	1100				cloudy		cancelled
		1400	23	310/2	5/2	clear	4	trouble with filter
		1700	24	276/3	5/3	clear	3-4	image motion
			25	316/3	0/3	clear	3-4	
Feb. 5	36	1200				cirrus	5-8	cancelled
		1600				cloudy		cancelled
Feb. 6	37	1300				cirrus	7-9	cancelled
		1600				cirrus		cancelled
Feb. 7	38	1300	26	339/3	7/3	clear	2-3	good run for this phase
		1400	27	287/3	8/3	clear	2-3	and zenith distance
		1500	28	230/3	1/3	clear	2-3	

STATION LOG JANUARY 1975

DATE	DAY(GMT)	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS

ATTEMPTS	SUCCESSFUL MEASUREMENTS
3/0	1/0
2/2	1/2
17/3	11/3
1/4	0/4

TOTALS FOR QUARTER

17/0	6/0
19/2	10/2
65/3	49/3
4/4	1/4

APPENDIX B

The Lunar Laser Calibration Data

from

29 August, 1974 to 11 February, 1974

APPENDIX B

System Calibration Data

The following pages contain the calibration constants for the quarterly period covered by the present report. The categories A-D are explained below.

A. This column contains the uncorrected calibration constant for the entire lunar laser ranging system as measured by the light emitting diode. Due to differing cable lengths for the calibration system, this value is approximately 30 nanoseconds higher than the actual system calibration value. It is, however, an accurate measure of the relative shift in the calibration value on a day-to-day basis.

B. This column shows the results of calibrating only the relative delays between the photodiode and photomultiplier sides of the ranging system using a separate time-to-pulse-height converter and a pulse-height analyser. When available the column also gives a letter code indicating the single shot uncertainty for any given night. The single shot uncertainty is keyed to the following code: A = ± 0.4 nanoseconds; B = $\pm .5$ nanoseconds; C = ± 0.6 nanoseconds; D = ± 0.7 nanoseconds; E = $\pm .8$ nanoseconds; F = ± 1.0 nanoseconds; G = ± 1.2 nanoseconds; H = ± 1.4 nanoseconds; I = ± 1.7 nanoseconds; J = ± 2.0 nanoseconds; K = ± 2.4 nanoseconds; L = ± 2.9 nanoseconds; M = ± 3.5 nanoseconds; N = ± 4.2 nanoseconds. The absence of a letter will indicate the single shot uncertainty of J.

C. This column gives the arithmetic mean of the feedback calibration return through the entire lunar ranging system as recorded during the actual lunar ranging by the system teletype.

D. This column shows the results of adding either the 13.9 or -2.9 nanosecond geometric corrections to column C. The units have been changed to tenths of nanoseconds and a minus sign added to coincide with how this additive constant appears on the preliminary data cards. Letters A,B,C,D, follow the corrected calibration constant to indicate the relative accuracy of the calibration where: A = ±200 picoseconds; B = ±400 picoseconds; C = ±600 picoseconds; D = ±1000 picoseconds; and E = 1.0-1.5 nanoseconds.

AUGUST - SEPTEMBER CALIBRATIONS, 1974

31000f V=2900 Disc.=3.0 G=0 Delay box out

DAY(GMT)	A	B	C	D*
241	----	J	13.5A	-268B
241	----	J	15.6A	-289B
242	----	J	14.0A	-275B
243	12.4	J	13.7A	-270B
244	6.7	J	----	-211C
245	----	J	13.9A	-272B
246	----	-	----	
247	12.4	J	14.3A	-276B
248	12.5	J	14.6A	-279B
249	12.8	J	14.2A	-275B
250	12.4	J	14.2A	-275B
251	----	J	14.3A	-276B
252	13.1	J	14.2A	-275B
253	12.5	J	14.9A	-287B
254	12.3	J	14.3A	-276B

*Lowered by 0.6 nsec on December 1 to account for the effects of a close gate pulse

SEPTEMBER - OCTOBER CALIBRATIONS, 1974

31000f V=2900 Disc. = 3.0

DAY (GMT)	A	B	C	D*
269	12.2	J	14.9B	-282C
270	13.9	J	14.3A	-276B
271	13.0	J	14.2B	-275C
272	----	J	14.2B	-275C
273	11.0	J	14.2A	-275B
274	11.9	J	14.5A	-276B
275	11.1	J	13.8A	-271B
276	----	-	----	
277	----	-	----	
278	13.1	J	13.8A	-271B
279	12.1	J	14.2B	-275C
280	----	-	----	
281	----	J	13.9A	-272B
282	11.3	J	13.7B	-270C
283	12.8	J	13.9A	-272B

*Lowered by 0.6 nsec on 1 December to account for the effects of a close gate pulse

OCT.-NOV. 1974 CALIB.

31000f V-2900 Disc.-3.0 G-0 Delay box out

DAY(GMT)	A	B	C	D*
293	21.9	J	18.7C	-320D
294	----	-	----	----
295	----	-	----	----
296	----	-	----	----
297	----	-	----	----
298	22.4	I	19.8B	-331C
299	----	J	19.7A	-330B
300	22.6	J	19.6A	-329B
301	21.1	J	19.5A	-328B
302	23.7	J	----	-328D
303	23.5	J	19.4A	-327B
304	----	J	19.7C	-330B
305	21.4	J	18.8B	-321C
306	----	I	19.4B	-327C
307	22.4	I	20.0A	-333B
308	----	-	----	----
309	21.6	J	----	-333D
310	22.9	I	19.9B	-332C

* Lowered by 0.6 nsec. on Dec. 1 to account for effects of close gate pulse.

NOV.-DEC. 1974 CALIB.

31000F V= 2900 G= 0 Disc.= 3.0 New shutter

DAY (GMT)	A	B	C	D
323-324	21.1	K	18.0A	-319A
324-325	22.1	I	18.1A	-320A
325-326	21.9	J	18.1A	-320A
326-327	----	I	18.1B	-320B
327-328	21.1	-	-----	-320B
328-329	21.8	J	18.6A	-325A
330	21.7	J	18.8B	-327B
331	22.2	J	18.3A	-322A
332	----	K	18.3A	-322A
333	22.1	-	-----	-322A
334	21.9	K	20.1A	-340A
335	22.4	-	-----	-----
336	----	-	-----	-----
337	----	-	-----	-----
338	22.0	J	-----	-340A
339	23.2	-	-----	-----
340	----	-	-----	-----
341	24.4	K	17.5A	-314A

DEC.-JAN. 1975 CALIB.

31000f V.= 2900 D=3.50

DAY (GMT)	A	B	C	D
356	----	J	----	-361D
V.=2950 D=3.70				
357	25.6	J	----	-361D
358	20.0	-	----	-----
V.=2700 G=4	Int.=5	Diff=5	d=2.0	
359	----	-	----	-----
360	----	-	----	-----
361	20.2	-	----	-----
362	19.3	-	----	-----
363	----	-	----	-----
364	19.5	-	----	-----
365	18.8	-	----	-----
1	----	-	----	-----
2	----	-	----	-----
3	21.7	-	----	-----
4	20.0	J	----	-305D
V.=2850 D=3.3				
5	----	-	----	-----
6	19.4	J	----	-299D

JAN.-FEB. 1975 CALIB.

31000F V.=3000 G=2 Int.=10 Disc.=4.20

DAY (GMT)	A	B	C	D
17	----	J	12.6	-265D
18	----	-	----	-----
19	----	-	----	-----
20-21	----	J	13.2	-271A
V.=3000 G=2	Int.=10	Disc.=4.20	Longer delay cable	
21-22		I	21.6	-355A
23	----	-	----	-----
24	----	-	----	-----
25	28.1	J	22.0	-359B
26	28.0	J	21.4	-353B
27	----	J	22.0	-359B
28	----	-	----	-----
29	----	-	----	-----
30	----	-	----	-----
31	26.8	-	----	-----
32	----	-	----	-----
33	----	-	----	-----
34	----	-	----	-----
35	26.2	J	20.7	-346A
36	27.3	-	----	-----
37	29.4	-	----	-----
38	26.4	J	22.2	-361A